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RTCA Special Committee 186, Working Group 5

ADS-B UAT MOPS

Meeting #3

Draft 1 of Section 1

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SUMMARY
Presented here is Draft 1 of Section 1 of the UAT MOPS.

1 PURPOSE AND SCOPE

1.1 Introduction

This document outlines Minimum Operational Performance Standards for airborne equipment to support Automatic Dependent Surveillance - Broadcast (ADS-B) through a Universal Access Transceiver (UAT). ADS-B is a system by which aircraft and certain equipped surface vehicles can share position, velocity, and other information with one another (and also with ground-based facilities such air traffic services) using fairly straightforward radio broadcast techniques. UAT is a multi-purpose aeronautical datalink system intended to support not only ADS-B, but also Flight Information Service - Broadcast (FIS-B), Traffic Information Service - Broadcast (TIS-B), and supplementary/secondary ranging and positioning capabilities. While UAT has been expressly designed as a multi-purpose datalink system, the focus of this document is on its provision of ADS-B capabilities.

The standards contained in this document specify desired system characteristics that should prove useful to designers, manufacturers, installers and users of UAT equipment. Compliance with these standards is recommended as one means (but not necessarily the only means) of ensuring that the equipment will satisfactorily perform its intended functions under conditions normally encountered in routine aeronautical operation. Some or all of these standards could be referenced by appropriate government agencies for certification and operational approval. Any such regulatory application of this document, or any part of it, is solely the responsibility of appropriate government agencies.

Since the basic equipment implementation includes computer processing, RTCA/DO-178B, *Software Considerations in Airborne Systems and Equipment Certification*, should be considered. Application of the software requirements of RTCA/DO-178B should take into account the level of criticality of supported functions, consequences of equipment failure, and the presence and effectiveness of any fault-monitoring features.

<u>Section 1</u> of this document provides information and assumptions needed to understand the rationale for the equipment characteristics and requirements stated in the remaining sections. It describes typical equipment operations and operational goals, as envisioned by the members of Special Committee SC-186, and, along with RTCA/DO-242, *Minimum Aviation System Performance Standards for ADS-B*, forms the basis for the standards stated in Sections 2 and 3. A brief description of the other capabilities of UAT (namely, FIS-B, TIS-B, and ranging features) is also included

<u>Section 2</u> contains the Minimum Performance Standards for the equipment. This specifies the required performance under standard operating conditions, as well as stressed physical environmental conditions. Also included are recommended bench test procedures to demonstrate equipment compliance with the stated minimum requirements. While the emphasis in this document is on UAT's support of ADS-B, performance standards for UAT's other features (FIS-B, TIS-B, and ranging) are discussed to the extent that they are supported at the UAT physical. The reader is directed to RTCA/DO-xxx, *Minimum Aviation System Performance Standards for Flight Information Service - Broadcast (Revision A)*, and other applicable documents for a more complete treatment of UAT performance standards for these other features.

Section 3 describes the performance required of installed equipment. Tests for the installed equipment are included when performance cannot be adequately determined through bench testing.

Section 4 describes the operational performance characteristics of the installed equipment, features, and controls.

Appendix A

Appendix B

Appendix I

Several different avionics architectures are possible for airborne UAT equipment for the provision of ADS-B. The supporting hardware could exist as separate, stand-alone equipment; or it could be incorporated within other on-board equipment. As a result, equipment designers and manufacturers have considerable latitude in configuring UAT to support various ADS-B applications, as well as tailoring those configurations to various classes of users.

The word “equipment” as used in this document includes all components and units necessary for UAT to properly perform its ADS-B functions. For example, the “equipment” for UAT may include a navigation sensor with timing signal, , computer processor, transceiver with associated antenna, and power supplies, etc. In this example, all of the mentioned components and units comprise the “equipment.” It should not be inferred from this example that each UAT design will necessarily include all of the foregoing components or units. This will depend on the specific design chosen by the manufacturer.

It should be noted that this document specifies *minimum* operational performance standards for UAT's ADS-B function. Conceptually, ADS-B can support a wide range of applications and, as described in RTCA/DO-242, some are considered "advanced" in that they introduce new relationships between equipment, automation, pilots, and controllers. The performance standards in this document are geared more toward the basic ADS-B applications as defined in RTCA/DO-242. Performance standards for functions or components that apply to capabilities that exceed the stated minimum requirements are identified as optional features.

1.2 System Overview

ADS-B is a system by which aircraft and certain equipped surface vehicles can share position, velocity, and other information with one another. The term "state vector" is often used to refer to an aircraft's position and velocity as conveyed by ADS-B, and is broken down into horizontal position and velocity, and vertical position and velocity. With such information made available by ADS-B from other proximate aircraft, it is possible to establish the relative position and movement of those aircraft with reference to one's own aircraft. It is also possible for ground-based facilities to monitor ADS-B broadcasts to enable basic surveillance capabilities, or to supplement existing surveillance systems. Other data that could be shared by ADS-B include a description of the aircraft's intended flight path ("intent" data), aircraft type, and other information, all of which enhance ADS-B capabilities.

When compared to ADS as currently employed in some oceanic regions, the key distinctive of ADS-B is that it is one-way *broadcast* in nature. Under ADS-B, an aircraft periodically broadcasts its own state vector and other information without knowing, a priori, what other aircraft or entities may be receiving it. In addition, the broadcast is made without the expectation of an acknowledgement or reply. With oceanic ADS, on the other hand, provision of such information is usually patterned after two-way datalink protocols where the end participants are identified and acknowledgements are issued. Further rounding out the definition of ADS-B, it is *automatic* in the sense that no pilot or controller action is required for the information to be issued. It is *dependent surveillance* in the sense that the surveillance-type information so obtained depends on a suitable navigation and broadcast capability in the source aircraft.

ADS-B is considered by many to be a key enabling technology to enhance safety and efficiency is airspace operations. RTCA Special Committee SC-186 has documented, in RTCA/DO-242, a wide range of applications of ADS-B focused on those goals. These include basic applications, such as the use of ADS-B to enhance the pilot's visual acquisition of other nearby aircraft, as well as more advanced applications, such as enabling the conduct of closely-spaced parallel approach operations. Other applications involving airport surface operations, improved surveillance in non-radar airspace, and advanced conflict management are also described.

Some applications of ADS-B are focused on airport surface operations and suggest that it is appropriate for certain surface vehicles to also be equipped with ADS-B - sharing their state vector information with aircraft on the surface, or in-flight near the airport. Such vehicles might include, for example, snow removal equipment, crash/fire/rescue vehicles, or construction equipment near runways or taxiways. For simplicity in this document, the term "aircraft" will be used to refer, collectively, to aircraft and vehicles, as any necessary distinction can be readily established by context. Occasionally the term aircraft/vehicle (A/V) may also be used.

1.2.1 UAT System Overview

The UAT is a wideband multi-purpose datalink intended to operate globally on a single channel media, with a channel signalling rate of just over 1Mps. By design, the UAT media supports multiple broadcast services including FIS-B and TIS-B, in addition to ADS-B. This is accomplished using a hybrid media access approach that incorporates both time-slotted and random unslotted access. By virtue of its waveform, signalling rate, precise time reference, and message-starting discipline, UAT can also support independent measurement of range to most other participants in the media.

There are two basic types of broadcast transmissions - or *messages* - on the UAT channel: the ADS-B message, and the Ground Uplink message. The ADS-B message is broadcast by an aircraft to convey state vector and other information. The Ground Uplink message is used by ground uplink stations to uplink flight information such as text and graphical weather data, advisories, and other aeronautical information, to any aircraft that may be in the service volume of the ground uplink station. Regardless of the type, each message has two fundamental components: the message *payload* that contains user information, and message *overhead* that supports the transfer of the data.

1.2.2 UAT Media Access for ADS-B and Ground Uplink

UAT message transmissions are governed by a combination of time-slotted and random-access techniques. Figure 1-1 illustrates the basic UAT message timing structure called a UAT *frame*. A frame is one second long and begins at the start of each UTC (or GPS) second. Each frame is divided into two segments: one segment in which Ground Uplink messages are broadcast, and another in which ADS-B messages are broadcast. Each segment is further divided into message start opportunities (MSOs) spaced 250 µs apart for a total of 4000 MSOs per frame. This spacing represents the smallest time increment used by UAT for scheduling Ground Uplink or ADS-B message transmissions.

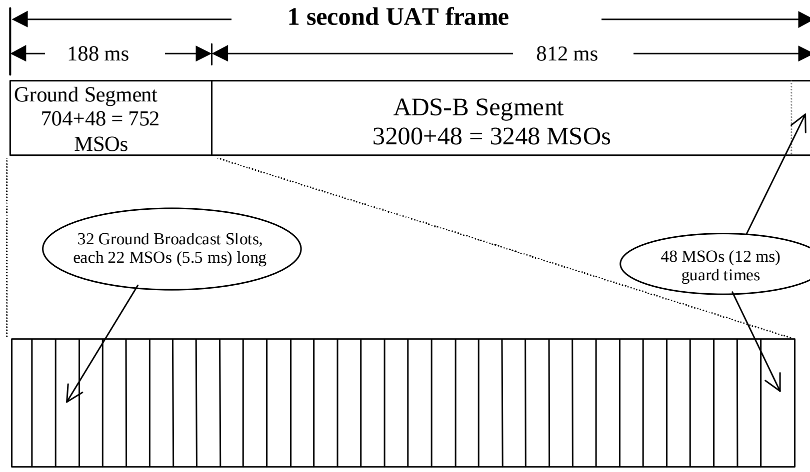

Figure 1-1: Basic UAT Frame Description

As shown in Figure 1-1, in each 1-second UAT frame the first 188ms segment is devoted to Ground Uplink message transmissions, and the remaining 812ms segment is devoted to ADS-B message transmissions.

1.2.2.1 Scheduling of Ground Uplink Message Transmissions

In actual implementation, it is envisioned that UAT-equipped aircraft will likely be in receiving range of more than one (and possibly several) ground uplink stations at any given time. To ensure that these multiple uplink broadcasts can be received by the airborne UAT without interference from one another, a scheduling discipline is applied to the uplinks. Each Ground Uplink segment is divided into 32 ground broadcast slots, and each nearby ground station is assigned one or more of the slots to broadcast uplink message(s) into its coverage volume. Assignment of the ground broadcast slots to the ground stations is made a priori, and allows for re-use of the slots by more distant stations similar to traditional radiofrequency allocation techniques.

Figure 1-1 also highlights the Ground Uplink segment of a typical UAT frame, which spans a total of 752 MSOs. Each ground broadcast slot spans 22 MSOs (i.e. 5.5ms long). A guard interval of 48 MSOs (12ms) is added after the last ground broadcast slot (and just prior to the beginning of the ADS-B segment of the UAT frame), yielding the total of 752 MSOs, or 188ms. Ground Uplink messages are therefore scheduled to begin only at MSO 1, MSO 23, MSO 45, and so on, up to MSO 683 (followed by the 48MSO/12ms of guard time). Adhering to this MSO-based scheduling scheme enables the airborne UAT to determine range to the ground uplink station. When coupled with information on the location of nearby ground uplink stations, and the ranges to those stations as supplied by UAT, a back-up positioning/navigation capability is possible.

Appendix *ii* provides more information on ground uplink message formats and protocols. Each message takes just over 4ms of the 5.5ms slot reserved for the uplink. The resulting gap provides over 200 nautical miles of propagation guard time between Ground Uplink messages on adjacent slots. Each Ground Uplink message provides 464 bytes of payload, and further definition of the payload is provided in RTCA/DO-XXX, *Minimum Aviation System Performance Standards for Flight Information Services - Broadcast (Revision A).*

1.2.2.2 Scheduling of ADS-B Message Transmissions

As shown in Figure 1-1, the ADS-B segment of each UAT frame is 188ms long, and spans 3248 MSOs. All ADS-B messages are transmitted in this segment of the frame. Each UAT-equipped aircraft makes exactly one ADS-B message transmission per frame, and selects, at random, from among the first 3200 MSOs in the segment to start transmission of the message. The last 48 MSOs in the segment provide guard time to account for possible timing drift. When coupled with the 48 MSO guard time at the end of the Ground Uplink segment, protection for clock drift is provided at both the beginning and end of the ADS-B segment. This provides some accommodation for clock drift in airborne units before there is the risk of ADS-B transmission overlap with a Ground Uplink message.

The random selection of an MSO for the start of an aircraft's ADS-B message is intended to prevent two aircraft from systematically interfering with each other's ABD-B message transmissions. Adherence to the MSO-based timing scheme enables the receiving UAT to determine range to the UAT that issued the message. This information could be used in validity checks of the position data conveyed in the ADS-B message itself.

1.2.3 ADS-B Message Structures

As mentioned above, each ADS-B message is made up of two fundamental components. The message overhead facilitates the physical layer handling of the message, and is described in more detail in Section 2. The message payload, on the other hand, contains the data of interest to potential user applications. Each ADS-B message contains at least the Basic State Vector (SV) payload (namely, horizontal position and velocity, and vertical position and velocity). Optionally, an ADS-B message may also include a Supplemental payload, in addition to the SV payload. Information on the aircraft's intended flight path is one example of the type of data that might be conveyed in a Supplemental payload. There are several different types of Supplemental payloads, and the type of payload is identified in the payload itself. If the message contains only the SV payload, it is called a Basic ADS-B message; if it also includes a Supplemental payload, it is referred to as an Extended ADS-B message.

Figure 1-2 illustrates the fundamental ADS-B message payload structure. Both the SV payload and the Supplemental payloads are fixed at [16] bytes each. All ADS-B messages include at least the SV payload, and the Extended ADS-B message also includes only one Supplemental payload (per message).

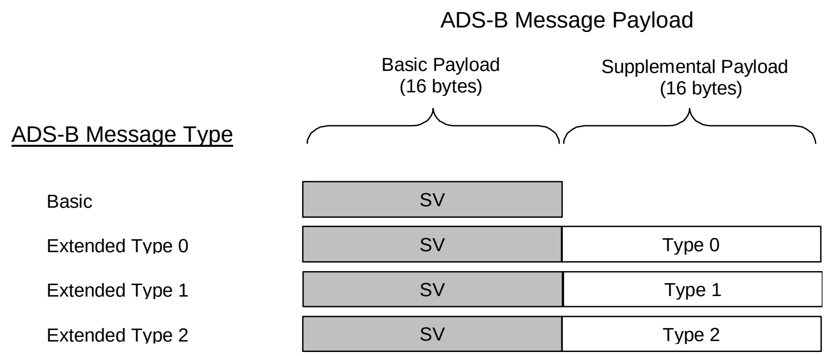

Figure 1-2: UAT ADS-B Payload Structure

In most scenarios, SV data are very dynamic - reflecting the movement and acceleration of the aircraft issuing the messages. By virtue of this message structure, then, SV data are issued at an average 1Hz rate, regardless of whether or not a Supplemental payload has been appended. This ensures that SV data (which are changing values rapidly) are issued frequently, thereby enabling UATs receiving the data to support applications with fresh information. In addition, because the SV data is part of every message, it could also be used to correlate various ADS-B message types, thereby eliminating the need for a unique address to perform such correlation.

The transmission rate of each message type is determined by the availability of the data that are conveyed in the various Supplemental payloads, as well as by the intended use of the data in the operational application. At one extreme, for example, a surface vehicle may transmit only the Basic ADS-B message, and never issue an Extended message with a Supplemental payload. An aircraft engaged in an operation based on ADS-B for which additional information is specified, on the other hand, may issue Extended ADS-B messages in a defined rotation cycle to ensure that Supplemental data necessary for the application are readily available and updated for the receiving UAT. Scheduling of transmission of the various Extended ADS-B message types is based on a specified message rate per *transmission epoch.* Within each transmission epoch, for example, each participating aircraft may be required to transmit at least one of each required message type, in accordance with the operational application being supported. Detailed information and requirements for payload composition and message transmission are included in Section 2.

1.3 Operational Goals

(Material from 1090 MOPS may be imported to here)

1.4 Assumptions

1.5 Test Procedures

The test procedures specified in this document are intended as one means of demonstrating compliance with the specified performance requirements. Although specific test procedures are cited, it is recognized that there are other suitable methods, and that these other procedures may be used if they provided at least equivalent confidence that the requirements are satisfied. In such cases, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternate procedures.

The specified order of tests suggests that the equipment be subjected to a succession of tests as it moves from design, and design qualification, into operational use. For example, compliance with the requirements of Section 2 shall have been demonstrated as a precondition to satisfactory completion of the installed system tests of Section 3.

a. Environmental Tests

Environmental test requirements are specified in Section 3. The procedures and their associated limits are intended to provide a laboratory means of determining the electrical and mechanical performance of the equipment under environmental conditions expected to be encountered in actual operations.

Unless otherwise specified, the environmental conditions and test procedures contained in RTCA Document No. DO-160C, *Environmental Conditions and Test Procedures for Airborne Equipment*, will be used to demonstrate equipment compliance.

b. Bench Tests

Bench test procedures are specified in Section 2. These tests provide a laboratory means of demonstrating compliance with the requirements of Section 2. Test results may be used by equipment manufacturers as design guidance, for monitoring manufacturing compliance and, in certain cases, for obtaining formal approval of equipment design.

c. Installed Equipment Tests

The installed equipment test procedures and their associated limits are specified in Section 3. Although bench and environmental test procedures are not included in the installed equipment test, their successful completion is a precondition to completion of the installed test. In certain instances, however, installed equipment test may be used in lieu of bench test simulation of such factors as power supply characteristics, interference from or to other equipment installed on the aircraft, etc. Installed tests are normally performed under two conditions:

1. With the aircraft on the ground and using simulated or operational system inputs.

2. With the aircraft in flight using operational system inputs appropriate to the equipment under test.

Test results may be used to demonstrate functional performance in the intended operational environment.

d. Operational Tests

The operational tests are specified in Section 4. These test procedures and their associated limits are intended to be conducted by operating personnel as one means of ensuring that the equipment is functioning properly and can be reliably used for its intended function(s).

1.6 Definition of Terms

The definition of some key terms used throughout the document is provided below.

UAT Frame – The one second interval between UTC (GPS) one second time marks

Transmission Epoch – The interval within which any required ADS-B message is transmitted at least once. This corresponds to 4 UAT frames (or seconds).

Message – The actual RF transmissions on the UAT channel. There are fundamentally two message types: ADS-B messages and Ground Uplink messages

Message Payload – The portion of the message that carries data that will be consumed by application systems outside the UAT system.

Field – The elements of ADS-B message payload. Most of these elements are enumerated in RTCA DO-242 (e.g., Latitude, Longitude, etc.)

Reports – The encapsulated payload of received messages that is forwarded to on-board application processors